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Two aspects of the operation and maintenance of the Suburban Park School District (SPSD) facilities are analyzed: (1) The allocation of funds to operation and maintenance, and (2) the individual custodial workloads. The maintenance and operation expenditures are divided into three categories (custodial salaries, operation expenditures above and beyond custodial salaries, and plant maintenance expenses) and are compared with national norms. The allocation of workloads for custodial staff members is analyzed in terms of efficiency, management's demand for custodians' time, and equalization of duties among custodians. A mathematical model is also constructed to facilitate administrative decision making in the areas of capital expenditures for and manpower utilization of maintenance equipment. It investigates the trade-off between men and machines in the floor scrubbing and water pickup processes. Four recommendations to SPSD resulted from the study: (1) Reevaluate the work assignments and task efficiencies of the custodians, (2) maintain present custodial staff size, (3) reassign individual custodial workloads to promote equalization of assigned duties, and (4) purchase the optimal mix of cleaning machines. (HW)

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and

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January 1968

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FOREWORD

School facilities exist to provide a comfortable and healthy environment in which the educational process can take place. Optimum standards of performance in the operation and maintenance of the school's physical plant will not only preserve and protect a structure of considerable public investment, but will also serve to safeguard the health of students and staff.

An important impression conveyed to the general public about an educational system is the outward appearance of its facilities. The public school administrator is consequently faced with the complex problem of providing both a safe and healthful environment and also an attractive and functional facility. To support these twin goals, the school administrator devotes approximately ten per cent of his annual budget to operating and maintenance costs.

It was with this understanding and philosophy of the problem in mind that Mr. John Haugo and Mr. Gary Mohrenweiser, research trainees in educational administration at the University of Minnesota, conducted this study. The techniques of operational analysis or a systems approach were used to approach this particular function. The further utilization of the general concept of operational analysis of education, cost-benefit and cost-utility studies, and various similar approaches to the determination of educational output may be viewed as possible extensions of the format of this study.

The Educational Research and Development Council of the Twin Cities Metropolitan Area, Inc. is extremely appreciative of the efforts of the co-authors in conducting the study described herein and making it available for distribution.

Van D. Mueller
Executive Secretary

INTRODUCTION: BACKGROUND AND STATEMENT OF THE PROBLEM

The Suburban Park School District facilities consist of three classroom buildings at two different sites. These buildings and the surrounding grounds are maintained by a staff of eleven custodians who are responsible to the school district's superintendent. (See Appendix A) The school maintains a high standard of performance in the operation and maintenance of the physical facilities for preservation of the public investment and protection of its student occupants.

Suburban Park allocates approximately 14 per cent of its annual budget to operational expenses. The custodial activities are implemented through the assistance of a small range of mechanical devices, as illustrated in Appendix B. Among the immediate questions in this area facing the superintendent are those pertaining to the appropriate levels of manpower and expenditures for maintenance activities and what types of capital equipment would best supplement the present custodial staff.

In response to these problems this report has the three following research objectives:

1. Analysis of allocation of financial resources to operations and maintenance.

2. Comparison of the individual custodial workloads with each other and with accepted norms.

3. Construction of a mathematical model to facilitate administrative decision-making in the areas of capital expenditures for maintenance equipment and manpower utilization of such equipment.

Negligible published data was found to be available in regard to these topics, with the exception of the existence of tabulated averages

and norms for overall expenditures and individual workloads. A list of the relevant references can be found in the attached bibliography, and definitions of the key terms used in this report are provided in Appendix C.

METHODS AND RESULTS

A Comparative Analysis of Plant Operation and Maintenance Expenditures

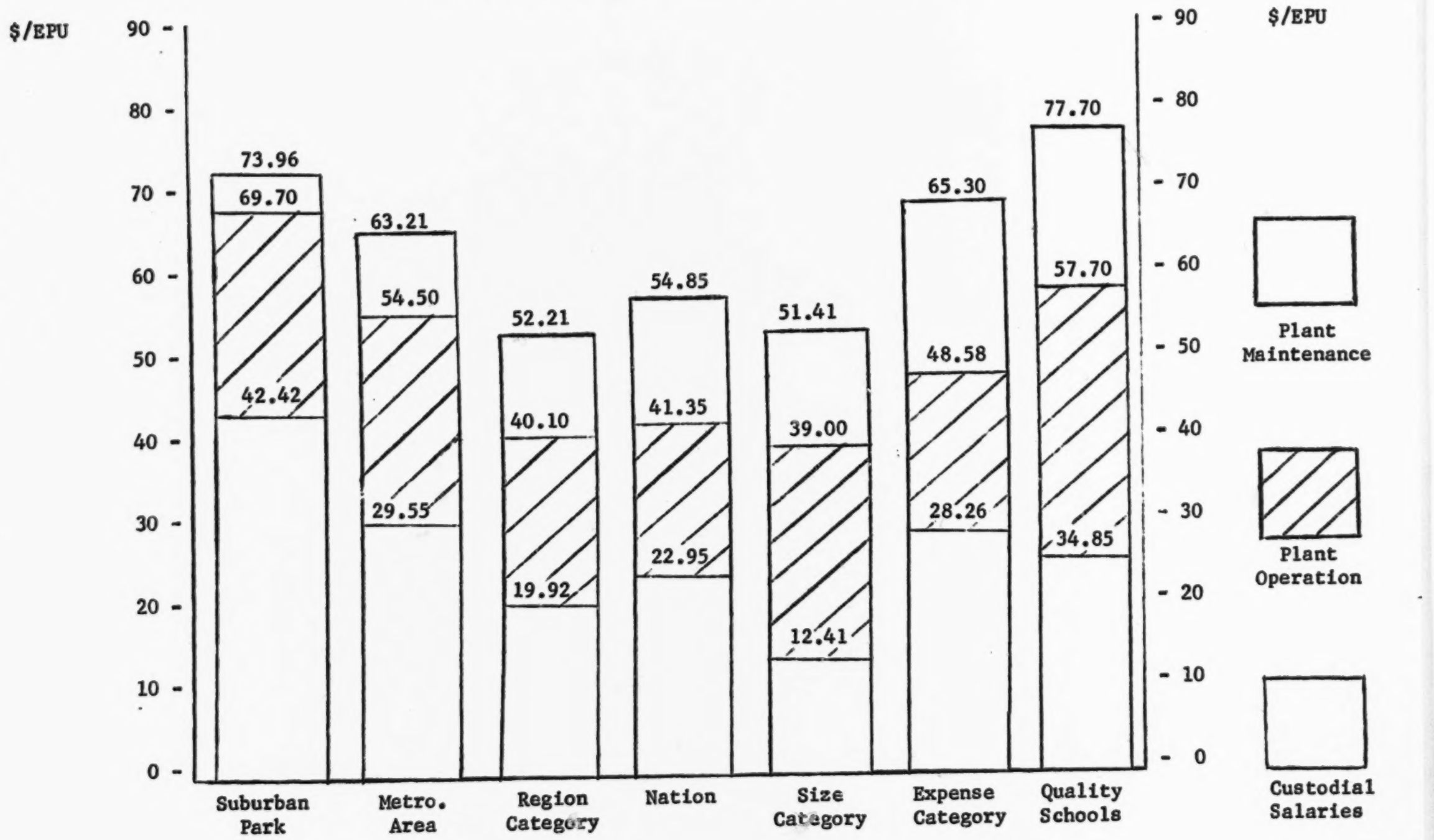
The first objective of this report is to review the current operation and maintenance function at Suburban Park with respect to comparative expenditures. An overview of all aspects of operation and maintenance costs is necessary to determine the existing allocation of funds for this function. Norms for expenditures will be used in this analysis to resolve any discrepancies in its operation and maintenance budget.

Data used for comparative purposes was gathered from a nationwide sample of school districts as reported in the January 1967 issue of School Management and in a survey of school financing by the Educational Research and Development Council (ERDC) of the Twin Cities Metropolitan Area, Inc. These surveys are annual studies that analyze all phases of school expenditures. The current school budget at Suburban Park is used to determine how the budget components are devoted to various aspects of the school program.

Figure 1 is a bar graph showing comparative median plant maintenance and operation costs. The vertical scale is in dollars per expenditure pupil units. Various categories of schools are represented by the bars on the horizontal axis. The metropolitan school category includes 41 school districts in the Twin City Area. School districts in eight neighboring states make up the region category. The size and expense categories represent schools throughout the nation that are approximately the same size as Suburban Park and spend about the same amount per pupil for net current expenditures. Quality schools consist of a sample from the top

FIGURE 1

COMPARATIVE PLANT MAINTENANCE AND OPERATION COSTS



10 per cent of the schools throughout the nation according to dollars per expenditure pupil units spent for all education costs. The majority of these schools are in the New England states and thus probably are not a just comparative criterion.

Although maintenance and operations expenditures can be subdivided into a large number of categories, only three subdivisions are used in Figure 1. The largest single expenditure, custodial salaries, is the darkened part of the bar; the cross-hatched area includes operation expenditure, above and beyond custodial salaries; and the upper sector of the bar designates plant maintenance expenses.

It can be seen from Figure 1 that Suburban Park is higher than all categories except the Quality School category in total maintenance and operation expenditures. In plant operation costs it is $12.00 per EPU higher than any category. Custodial salaries at Suburban Park are perhaps the highest comparative expenditure. Plant maintenance expenses are disproportionately low. Possibly maintenance expenses are relatively small because of the comparatively new facilities at Suburban Park which do not demand as much maintenance as older buildings.

The findings shown in Figure 1 do not present the entire picture as far as maintenance and operation costs are concerned. In addition to determining the dollars per EPU devoted to the operation and maintenance function, it is necessary to compare the percentages of the net current expenditures that are allocated to the function. Two schools could conceivably spend the same amount per pupil for operation and maintenance, but because their dollars spent per EPU differs considerably the percentages would vary.

Table 1 represents the median percentages of the NCE used for plant operation and maintenance in the various comparative categories of schools.

TABLE 1

MEDIAN PER CENTS OF NET CURRENT EXPENDITURE (NCE) USED FOR SCHOOL PLANT OPERATION AND MAINTENANCE

CATEGORY	OPERATION	MAINTENANCE	TOTAL
Metro. Area	11.49	1.89	13.38
Region	9.55	2.79	12.34
Nation	9.51	3.10	12.61
Size	8.96	3.14	12.10
Expense	9.65	5.33	14.98
"Quality" Schools	9.80	3.40	13.20
Suburban Park	13.42	.82	14.24

We can observe that Suburban Park again is relatively high in expenditures for this function. The 13.42 per cent of their NCE that is spent for operation alone is greater than what the median school in most categories spends for both operations and maintenance. The fact that schools in the same expense category as Suburban Park spend a higher total percentage can be attributed to the higher maintenance expense that the median school in this category pays.

We note in Figure 1 that the highest single expenditure in the plant operation and maintenance function was custodial salaries. For this reason the median number of custodians for schools in various cateogires is discussed in this section. Table 2 shows the median school custodial sizes per 1,000 students.

TABLE 2

SCHOOL CUSTODIAL STAFF STANDARDS
(NO. OF CUSTODIANS/1000 STUDENTS)

CATEGORY	STANDARD
State Dept. of Ed.	5.00
Region	5.35
Nation	6.01
Size	5.60
Expense	6.76
Suburban Park	7.48

The Minnesota State Department of Education recommends a minimum of five custodians per 1,000 students. The findings show that the media for each category is higher than this recommendation. Suburban Park has 7.48 custodians per 1,000 students. This ratio is higher than the ratio for any category of which Suburban Park is a member.

A more complex model for determining the optimal number of custodians needed for a school district is known as Pattington's Formula. Five determinants are considered in applying this formula. The factors involved are the number of teachers, the number of pupils, the number of school rooms (with an average classroom defined as one containing 1,000 square feet),the number of square feet of building area, and the number of acres of upkept ground. Basically the formula weighs the various factors and then divides the total number of custodians determined for the five factors by five. The various factors call for one custodian for each eight teachers, 225 pupils, 11 rooms, 1500 square feet of building area, and two acres of upkept grounds.

Figure 2 shows the computation of Pattington's Formula for the Suburban Park School District. According to the formula, they should have a staff of 10.33 custodians. This finding correlates closely to the existing staff of eleven custodians. The size of the building and amount of grounds to be upkept are the two factors which affect the finding most.

Several conclusions can be drawn from the findings of this section. First of all, comparative data show that the Suburban Park School District is paying significantly more for plant maintenance and operation than the median schools in the Twin City Area, the region, and the nation. It also has higher expenditures than schools of comparable size and school expenditures per student. These findings are apparent in terms of both expenditures per pupil unit and per cent of net current expenditures allocated to plant maintenance and operation.

A breakdown of total operation and maintenance expenditures indicates that Suburban Park School District spends a relatively small amount for maintenance. The fact that the majority of their facilities are new could account for this. A disproportionately high per cent of their budget is spent for custodial salaries. Although the number of custodians is high when compared to the median number of custodians per 1,000 students, an application of Pattington's five-factors formula reveals that Suburban Park's custodial staff size is consistent with this criterion instrument. The school district apparently has a relatively large facility for its school population because the number of rooms and amount of floor space contribute most to this figure.

FIGURE 2

PATTINGTON'S FORMULA

1. Number of Rooms / 11	=	$\frac{146}{11}$	= 13.27
2. Number of Teachers / 8	=	$\frac{78}{8}$	= 9.75
3. Number of Students / 225	=	$\frac{1470}{225}$	= 6.53
4. Sq. Ft. of Floor / 15,000	=	$\frac{162,000}{15,000}$	= 10.80
5. Acres of Grounds / 2	=	$\frac{22.6}{2}$	= 11.30
6. Sum of #1 through #5	=	$\frac{51.65}{5}$	= 10.33

Allocation of Custodial Duties

The objective of this section is to analyze the allocation of work-loads for members of the custodial staff. From this analysis will be derived three measures: (1) efficiency, (2) demand, and (3) equalization. These measures will be defined and discussed later in this section, after the total custodial needs are determined.

The Suburban Park school system at present employs 11 full-time (eight hour day) custodians. There is a head custodian, three day-time employees, and seven late afternoon and evening employees. The school system operates under the particular constraints of class schedules, extra curricular activities, P.T.A. groups, etc., all of which determine when and where custodial activities may and must take place. It is for this reason that the head custodian and the three day-time employees have been excluded from the following analysis. This exclusion should not be inter-

preted as implying that their duties are not meaningful and necessary, for indeed they are. However, because of the variety of duties performed by these employees, no meaningful and consistent evaluation of these activities can be made at the present time.

In preparation for the analysis of the allocation of custodial workloads, relevant information was collected for each of the seven night-time custodians. (See Appendix D) The following information was determined:

1. The number of square feet of classroom and classroom-like space cleaned per minute.
2. The number of square feet of corridor space cleaned per minute.
3. The number of flights of stairs cleaned, and the number of minutes used per flight.
4. The number of square feet of locker and shower room area cleaned per minute.
5. The number of square feet of gymnasium and auditorium area cleaned per minute.
6. The number of square feet of kitchen space cleaned per minute.
7. The length of time it takes to clean a lavatory room expressed in minutes per fixture. This was found to be a more accurate measure than the square feet measurement.
8. Total time in minutes spent in other cleaning duties and non-cleaning duties. This was assumed to be ten per cent of total time, or 45 minutes per day.

From the above information, each custodian's assignment could be extracted from the total custodial needs given in Figure 3.

The standards used in evaluation of custodial assignments are given in Table 3. There are many standards found in the educational literature but nearly all of them approximate the figures given below, which were adopted from the Educational Research and Development Council (ERDC) of

the Twin Cities Metropolitan Area, Inc. Under certain circumstances these figures have been revised to include consideration of carpeted and special areas.

TABLE 3

STANDARDS USED IN EVALUATION (ERDC)

Classrooms	60 sq. ft. per minute
Corridors	200 sq. ft. per minute
Stairways	5 minutes per flight
Kitchens	30 sq. ft. per minute
Locker and shower rooms	40 sq. ft. per minute
Gymnasium	200 sq. ft. per minute
Lavatories	4 minutes per fixture

The three measures relating employee performance to allocated work assignments are defined below.

DEFINITIONS

$$\text{Efficiency} = \frac{\text{time units suggested for assignments}}{\text{time units used for assignments}}$$

$$\text{Demand} = \frac{\text{time units suggested for assignments}}{\text{time units demanded (435 minutes ACB)}}$$

$$\text{Equalization} = \frac{\text{time units suggested for assignment}}{\text{average time units assigned}}$$

Efficiency is a per cent index measuring the rate at which a custodian completes a given task. No attempt was made to determine the quality of each custodian's performance. It was assumed that all tasks performed met

minimum standards which were determined and evaluated by custodial management. An example of the efficiency calculation is: to clean a certain area, the custodian actually used 100 minutes. From the standards given in Table 3, this same area should have been cleaned in 90 minutes, thus:

Time units suggested = 90 minutes
Time units used = 100 minutes

$$\text{Efficiency} = \frac{\text{time units suggested for assignment}}{\text{time units used for assignment}} = \frac{90 \text{ min.}}{100 \text{ min.}} = 90\%$$

An efficiency of less than 100 per cent may be interpreted as: a given individual is performing his tasks slower than should be expected. An efficiency greater than 100 per cent means that a given individual is completing his tasks more rapidly than what is to be expected in comparison to the given standards.

Demand is a per cent index relating the time which is suggested for an average day's assignments to the total number of minutes per day (435 after lunch and coffee break) for which the custodian is productively employed. An example of a demand calculation is: During an average day the custodian performs tasks which, when evaluated by given standards, require 460 minutes of his time. The school system employs the custodian for 435 minutes. Thus:

Time suggested for assignment = 460 minutes
Time units demanded (employed) = 435 minutes

$$\text{Demand} = \frac{\text{time units suggested for assignments}}{\text{time units demanded}} = \frac{460 \text{ min.}}{435 \text{ min.}} = 106\%$$

A demand above 100 per cent implies that management is asking more than a "fair share" from a given employee, while a demand of less than 100 per cent means that the employee could be expected to complete additional tasks during his employed time.

Equalization is a per cent index relating a given custodian's assignment to the average assignment of all custodians. The average assignment for all custodians at Suburban Park was 450 minutes. An example of an equalization calculation is: The time suggested for a day's tasks is 460 minutes (see demand example). Thus:

Time units suggested = 460 minutes
Average time units assigned = 450 minutes

$$\text{Equalization} = \frac{\text{time units suggested for assignment}}{\text{average time units assigned}} = \frac{460}{450} = 102\%$$

An equalization index above 100 per cent indicates that a given custodian is assigned an above average percentage of duties as compared to his fellow employees. An equalization index below 100 per cent implies a below average assignment. By definition, an equalization of 100 per cent means the individual is allocated an average job load.

Table 4 gives a detailed summary of the average cleaning assignments for each custodian, the average time units used for each task, and the time units suggested based upon given standards. From these totals, efficiency, demand, and equalization were calculated.

To facilitate comparison of efficiency, demand, and equalization levels for each individual, the values have been graphed in Figure 4, Figure 5, and Figure 6 respectively. The vertical axis illustrates the per cent index in each case, whereas the horizontal axis indicates the identifying number of the individual custodians.

Figure 4 indicates two extreme values of custodian efficiency. Custodian #5 and custodian #7 might be considered inefficient based upon the information available. However, before final conclusions may be drawn, the tasks assigned and performed by these men should be reviewed.

TABLE 4

CUSTODIAN CLEANING ASSIGNMENTS

ASSIGNMENT	TIME UNITS (Used)	TIME UNITS (Suggested)
Custodian #1		
Classrooms (13,440 sq. ft.)	210 min.	224 min.
Lavatories (20 fixtures)	60 min.	80 min.
Stairs (6 units)	25 min.	30 min.
Corridor (7,770 sq. ft.)	60 min.	39 min.
Other 10%	45 min.	45 min.
Total	400 min.	418 min.
Efficiency - 104% Demand - 96% Equalization - 93%		
Custodian #2		
Classrooms (16,200 sq. ft.)	270 min.	270 min.
Lavatories (31 fixtures)	70 min.	124 min.
Stairs (2 units)	10 min.	10 min.
Corridor (6,500 sq. ft.)	30 min.	32 min.
Other 10%	45 min.	45 min.
Total	455 min.	481 min.
Efficiency - 106% Demand - 110% Equalization - 107%		
Custodian #3		
Classrooms (9,500 sq. ft.)	155 min.	160 min.
Locker Rooms (3,072 sq. ft.)	50 min.	77 min.
Kitchen (2,880 sq. ft.)	100 min.	96 min.
Corridor (4,990 sq. ft.)	30 min.	25 min.
Lavatories (11 fixtures)	60 min.	44 min.
Stairs (2 units)	10 min.	10 min.
Other 10%	45 min.	45 min.
Total	450 min.	457 min.
Efficiency - 102% Demand - 105% Equalization - 102%		
Custodian #4		
Classrooms (4,080 sq. ft.)	120 min.	68 min.
Corridors (2,040 sq. ft.)	10 min.	10 min.
Lavatories (39 fixtures)	120 min.	156 min.
Gymnasium (2,100 sq. ft.)	20 min.	15 min.
Kitchen (3,000 sq. ft.)	100 min.	100 min.
Locker Room (2,400 sq. ft.)	60 min.	60 min.
Other 10%	45 min.	45 min.
Total	475 min.	454 min.
Efficiency - 96% Demand - 104% Equalization - 101%		

TABLE 4 (cont.)

Custodian #5

Classrooms (9,750 sq. ft.)	195 min.	165 min.
Corridors (8,070 sq. ft.)	50 min.	41 min.
Locker Room (1,900 sq. ft.)	50 min.	48 min.
Lavatory (10 fixtures)	35 min.	40 min.
Swimming pool area (2,100 sq. ft.)	60 min.	53 min.
Other 10%	45 min.	45 min.
Total	445 min.	392 min.

Efficiency - 88% Demand - 90% Equalization - 87%

Custodian #6

Classrooms (9,750 sq. ft.)	180 min.	165 min.
Corridors (4,920 sq. ft.)	80 min.	49 min.
Lavatories (27 fixtures)	60 min.	108 min.
Stairways (1 unit)	10 min.	5 min.
Kitchen (1,150 sq. ft.)	30 min.	38 min.
Library (2,540 sq. ft.)	65 min.	85 min.
Other 10%	45 min.	45 min.
Total	470 min.	495 min.

Efficiency - 105% Demand - 114% Equalization - 110%

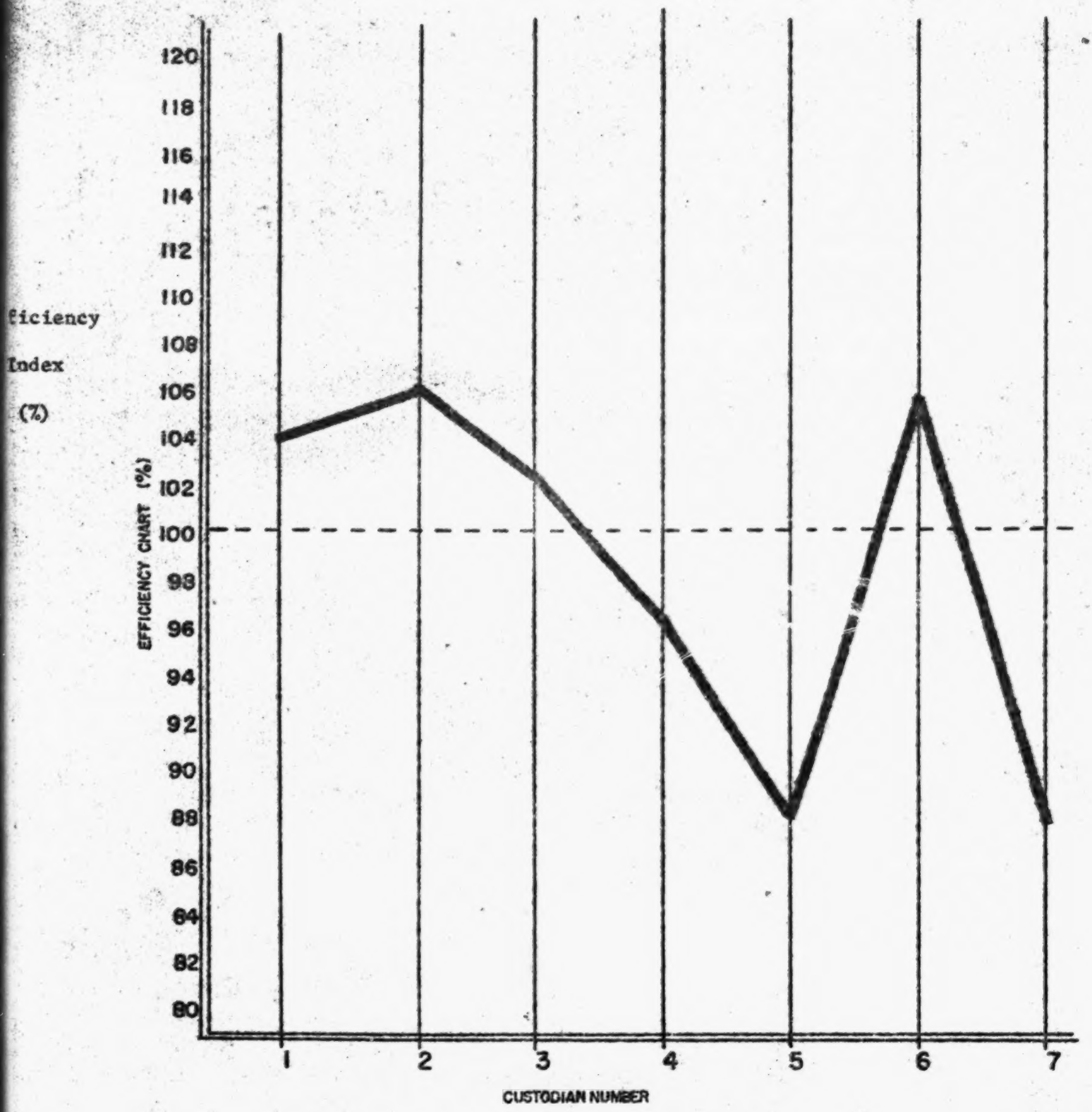
Custodian #7

Classrooms (800 sq. ft.)	15 min.	13 min.
Corridors (4,450 sq. ft.)	45 min.	22 min.
Lavatories (37 fixtures)	180 min.	148 min.
Stairs (5 units)	20 min.	20 min.
Gymnasium (3,900 sq. ft.)	20 min.	20 min.
Cafeteria, cleaning & set up tables	165 min.	168 min.
Locker Room	20 min.	14 min.
Other 10%	45 min.	45 min.
Total	510 min.	450 min.

Efficiency - 88% Demand - 103% Equalization - 100%

FIGURE 4

CUSTODIAL EFFICIENCY GRAPH



The general conclusion to be drawn from Figure 5 is that a slight (about 5 per cent) excess demand is placed upon the average custodian. Of the seven custodians studied, only two (custodian #1 and custodian #5) are asked to perform less than a standardized job as determined by the given norms. Two extreme values are indicated (90 per cent demand for custodian #5 and 114 per cent demand for custodian #6) which suggest possible re-assignment of demands placed upon the men. This condition is further indicated in Figure 6 which shows that custodians (#'s 1, 2, 5, 6) deviate significantly from an equalized work load. Special consideration should be directed at equalization by re-assignment of custodial duties for these men.

A Mathematical Model for Man-Machine Trade-off Decision-Making

The third part of this project, as stated in the introduction, was to build a mathematical model dealing with the trade-off between men and machines. This area was selected because, while there is a large selection of maintenance equipment on the market and many articles in the literature attesting to the value of this equipment, no specific criteria for deciding which types of equipment and how many for a given building could be found. The need for such a criterion is illustrated by the size of the maintenance budget and the prices of automated maintenance equipment.

This part of the project was performed in three steps. First, a basic model was set up. Actual figures for the Suburban Park school system were then inserted into this model and the "solution" was found. This solution could then be compared to the present case and corrective action, if necessary, could be taken.

FIGURE 5

CUSTODIAL DEMAND GRAPH

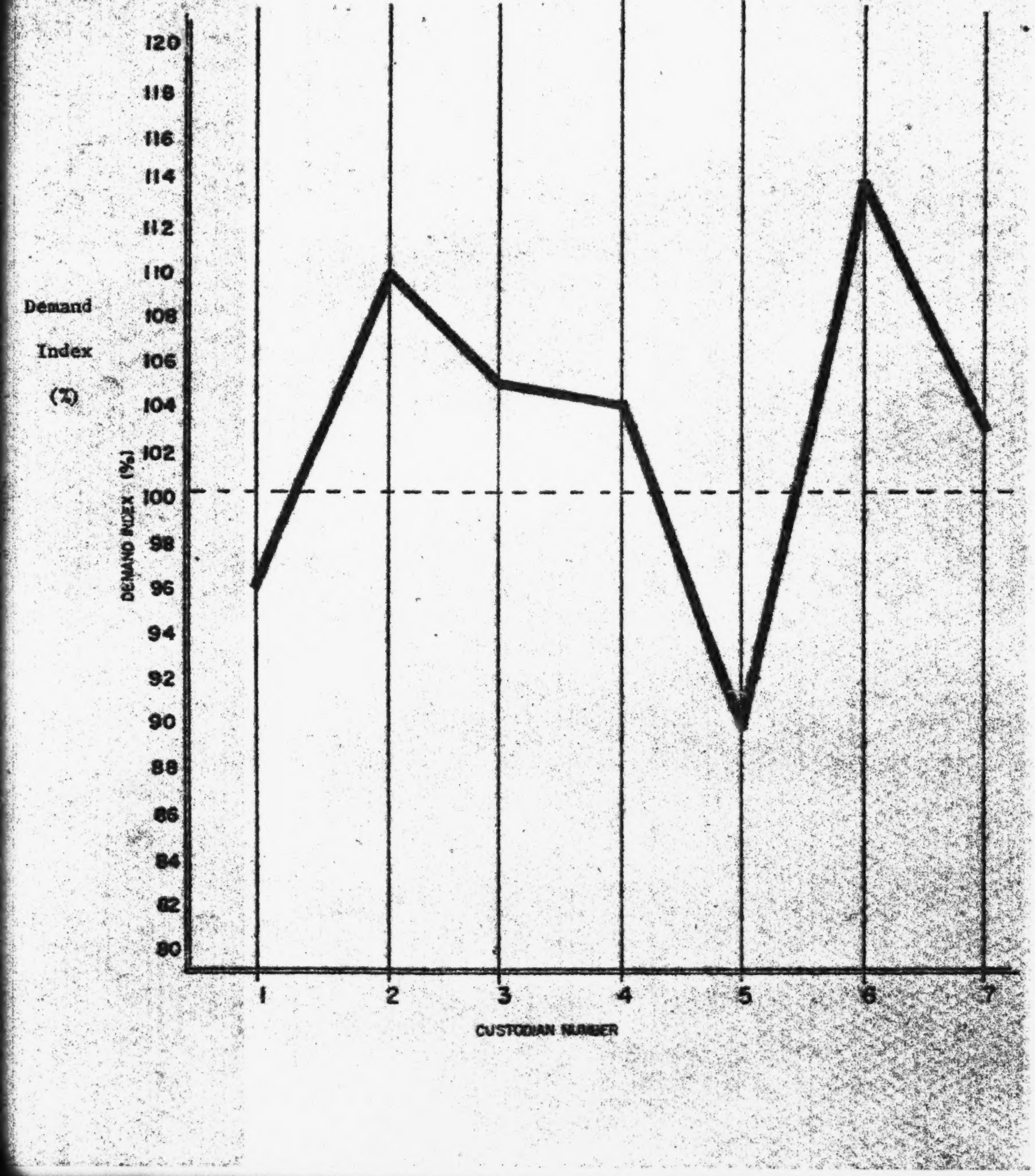
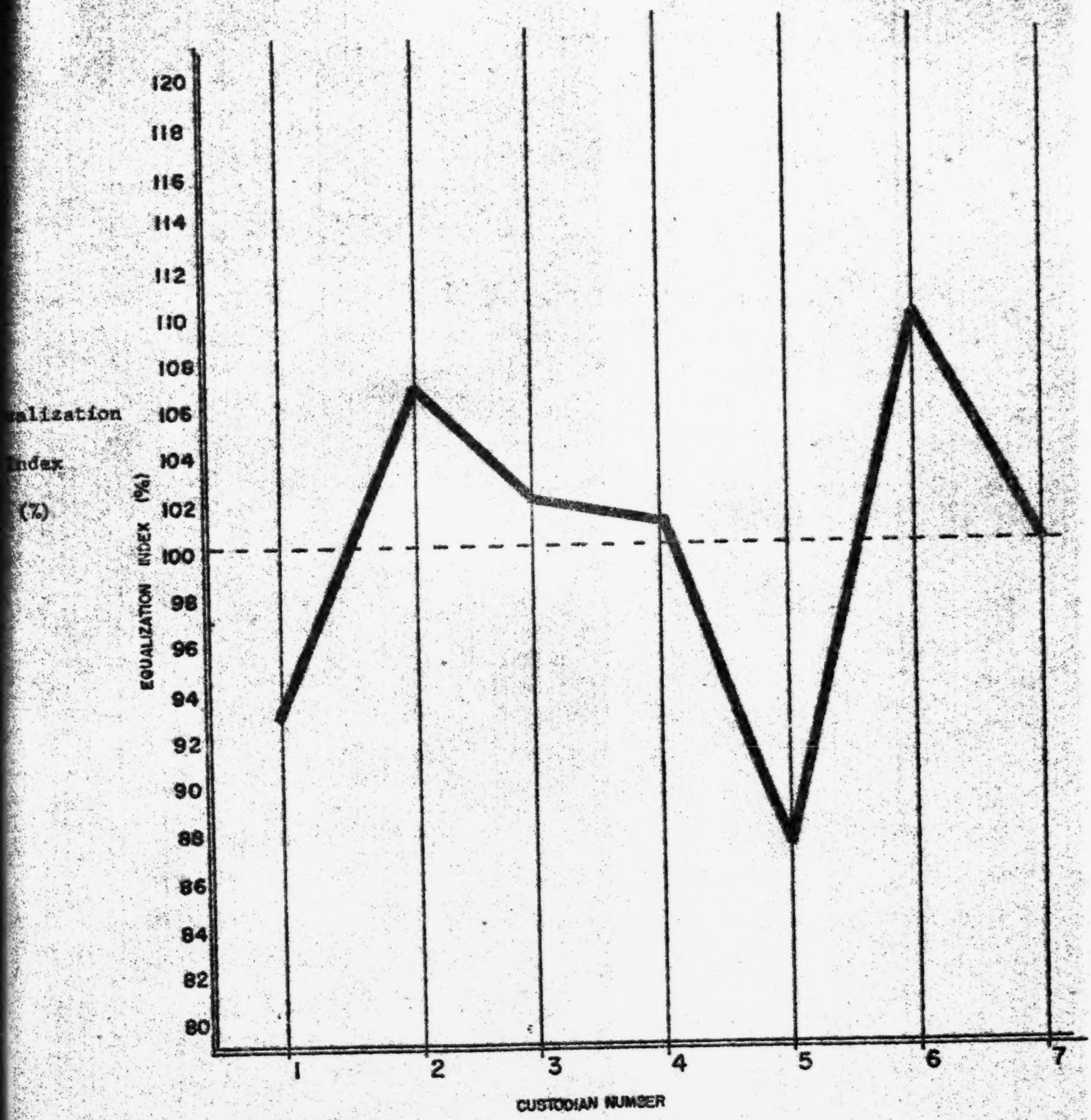


FIGURE 6

CUSTODIAL EQUALIZATION GRAPH



The model was limited to floor scrubbing and water pickup process for two reasons, First of all, this involves a major expenditure of time and money, and, secondly, the greatest range of equipment is available in this line.

The range of equipment varies from essentially all hand labor using a long-handled brush to scrub and a mop and pail to pick up the water, to semi-automated using an electric motor-driven brush to scrub and a separate wet-pickup vacuum to remove the water, to completely automated using a combination power scrubber and vacuum in one machine which will complete the job in a single pass.

The basic formulas used in the model are as follows:

$$\text{Cost for cleaning by hand labor} = \text{number of cleanings} \times \frac{\text{number of sq. ft. cleaned}}{\text{cleaning rate - man (sq. ft./hr.)}} \times \text{wage/hr.}$$

$$\text{Cost for cleaning by machine} = \text{number of cleanings} \times \frac{\text{number of sq. ft. cleaned}}{\text{cleaning rate - machine (sq. ft./hr.)}} \times \text{wage/hr.- man}$$

$$+ \text{number of cleanings} \times \text{machine operating cost/hr.} \times \frac{\text{number of sq.ft. cleaned}}{\text{cleaning rate - machine}}$$

$$+ \text{number of machines} \times \frac{\text{cost}}{\text{life}} + \text{interest rate} \times \text{number of machines} \times \frac{\text{cost}}{2}$$

Some basic assumptions in these equations are as follows:

1. The cost of pails, mops, and brushes are ignored in the hand operation. This cost over a period of time is so relatively small that it would not significantly affect the results.

2. The cost of detergents and cleaning solutions is not considered in either equation because this is relatively constant regardless of the equipment used and therefore would not affect the comparison.

3. The machines will depreciate completely over their life and their life is relatively independent of the number of hours used. This assumption is made because the operating cost per hour considers the normal wear and tear and the depreciation is then due mainly to the obsolescence of the machine.

4. The interest is calculated on the average investment in the machines. This method is believed to be accurate enough without making the equation unnecessarily complicated.

5. The direct cost of cleaning with a certain type of machine is the same regardless of the number of machines. For example, one machine in ten hours can do the same amount of work as two identical machines working five hours apiece. This yields the same total man-machine hours and the same total operating cost. The difference is the interest and depreciation on the additional machine.

6. The cost of cleaning is the total for some time period, usually one year. The number of cleanings is then the total for that time period.

7. The wage rate is charged only for the actual cleaning time. This assumes that the employees can be employed elsewhere for the rest of the time.

The cost equations are then subject to two constraints, a capital expenditure constraint and a time constraint. There is a limit on the amount of funds available at any one time to invest in equipment and there is also a maximum limit on the time period within which the maintenance task must be done. Going back to the example used above, if the maximum time allotted for the task is six hours, obviously two or more machines must be used.

The optimum solution to the model then is the minimum cost, given a specified maximum amount of capital expenditure, a maximum allotted time for the cleaning operation, and a given number of cleanings per year.

The model was then operated for the Suburban Park school buildings using various combinations of equipment at the three levels of automation.

The equipment range included, for comparison, all hand operation to well beyond the maximum amount of equipment deemed necessary by industry "rules of thumb". The equipment range used in the model was: all hand scrubbed and hand mopped; 2, 4, 6, or 8 of both machine scrubbers and wet vacuums; and two automatic scrubbers and 2, 4, 6, or 8 of both machine scrubbers and wet vacuums.

The machine scrubbers and wet vacuums were combined in a ratio of 1:1 because they have approximately the same operating rate and therefore the increased speed of a greater number of one could not be utilized without a proportionately greater number of the other.

The total floor area used for this model was 120,000 square feet. This area was divided into two sections. On the basis of our evaluation of Suburban Park floor space, 40,000 square feet (denoted SQFL in the equations) consisting of fairly open areas such as hallways, cafeterias and other large rooms would be suitable for use of an automatic scrubber. The other 80,000 square feet (denoted SQFS) consisting of moderately obstructed areas and smaller rooms would not be suited for use of an automatic scrubber. Hand scrubbing and machine scrubbing with wet vacuum could be done on the entire 120,000 square feet (SQFL + SQFS).

This division os the floor area and the use of varying numbers of different types of machines caused one machine equation to be the addition of two parts, one for the automatic scrubbers and one for the machine scrubber-wet vacuum combinations. The specific equations used to compute the floor cleaning cost for the Suburban Park schools are as follows:

$$\text{Cost of cleaning for one year by all hand labor} = \text{no. of cleanings} \times \frac{SQFL + SQFS}{SQFHM} \times COSTMH$$

$$\text{Cost of cleaning for one year by machine scrubber-wet vacuum} = \text{no. of cleanings} \times \frac{SQFL + SQFS}{SQFHS} \times COSTMH$$

$$+ \text{no. of cleanings} \times OPCHS \times \frac{SQFL + SQFS}{SQFHS}$$

$$+ \text{no. of machines} \times \frac{COSTS}{AGES} + \text{no. of machines} \times \frac{COSTS}{2}$$

$$\text{Cost of cleaning for one year by automatic scrubber \& machine scrubber-wet vacuum} = \text{no. of cleanings} \times OPCHS \times \frac{SQFS}{SQFHS}$$

$$+ \text{no. of cleanings} + \frac{SQFS}{SQFHS} \times COSTMH$$

$$+ \text{no. of machines} \times \frac{COSTS}{AGES} + \text{no. of machines} \times \frac{COSTS}{2}$$

$$+ \text{no. of cleanings} \times \frac{SQFL}{SQFHL} \times COSTMH$$

$$+ \text{no. of cleanings} \times \frac{SQFL}{SQFHL} \times OPCHL$$

$$+ \text{no. of machines} \times \frac{COSTL}{AGEL} + \text{no. of machines} \times \frac{COSTL}{2}$$

Other values used in the above equations which apply to the Suburban Park schools are as follows:

SQFHM	=	cleaning rate, hand scrub-mop, wet vacuum	= 400 sq. ft./hr.
SQFHS	=	cleaning rate, machine scrub	= 1500 sq. ft./hr.
SQFHL	=	cleaning rate, automatic scrub	= 4700 sq. ft./hr.
COSTMH	=	wage per hour	= $2.80
OPCHS	=	operating cost per hr., machine scrub	= $0.25
OPCHL	=	operating cost per hr., automatic scrub and wet vacuum	= $0.50

COSTS	=	initial cost, machine scrub	=	$750
COSTL	=	initial cost, automatic scrub	=	$2100
AGES	=	life in yrs., machine scrub	=	5
AGEL	=	life in yrs., automatic scrub	=	5
AINT	=	interest	=	5%

Number of cleanings per year ranged from 1 to 12.

As stated, these figures are appropriate for the Suburban Park school buildings and were derived from a variety of reliable sources. The following statements give a brief description of these values and tell how they were obtained:

1. The cleaning rates are standards taken from the November, 1960 issue of Buildings. They compared favorably with values used by the University of Minnesota custodial staff and those given by various equipment manufacturers.
2. The initial machine costs are the price ranges for similar models among various equipment manufacturers and distributors.
3. Both the cleaning rates and machine costs assume the combination scrubbers to be 24" models and the machine scrubbers to be 19" models. These could be considered medium-sized machines and, according to the literature, are the most popular and in general the most suitable sizes.
4. The machine lives were established through direct conversations with equipment distributors.
5. A large part of the opearting cost goes for the replacement of brushes and electricity to run the motors or recharge the batteries. For example, a brush costing $25 lasts approximately 200 hours for a cost of $ .125 per hour.

6. The five per cent interest is an average rate paid on school bonds.
7. The wage rates include the present average and a higher rate which may be applicable in the future.
8. The number of cleanings is varied over a wide range. The present number is three cleanings per year.
9. The actual calculation of the model using the above data was performed on a CDC, 1604 computer.

The results were printed out in a matrix such as the one shown in Appendix E. The amounts of equipment are shown by the figures across the top of the matrix. The first value is the number of automatic scrubbers and the second is the number of machine scrubber-wet vacuum units. For example: 0,0 means no machine usage; 1,2 means one automatic scrubber and two machine scrubber-wet vacuum units. The numbers from 1 to 12 down the left-hand side of the cost matrix are the number of cleanings per year. The cost numbers in the matrix are dollars per year.

The budget constraint was considered by listing the total initial investment for the amount of equipment given at the top of that column.

The time constraint was also considered by listing the number of hours needed to complete one cleaning operation for each amount of equipment introduced as a variable. When both automatic scrubbers and machine scrubbers-wet vacuums were used, the greatest time was usually that required for the machine scrubbers-wet vacuums to complete the 80,000 square feet. Therefore, the addition of more automatic scrubbers does not further affect this time while the addition of machine scrubbers-wet vacuums does.

One additional factor applies to the machine combinations using just one automatic scrubber, but this is not included in the cost matrix. One of the buildings is situated approximately one-half mile from the other two. Therefore, to clean the entire 40,000 square feet of open areas, the scrubber would have to be transported at each cleaning. This was arbitrarily assigned a value of $5 per cleaning for the man's time and the use of a truck. Therefore, the costs would be increased by $5 for one cleaning per year to $60 for twelve cleanings per year in the matrix. This amount is about 0.5 per cent of the total cost and consequently was disregarded.

This matrix can be used to find what amount of equipment will yield the minimum cost for a certain number of cleanings within the framework of budget and time constraints. Another answer readily found is the additional cost of obtaining greater flexibility through the purchase of more machines.

The values used are appropriate at the present time. New matrices for new variables can very easily be obtained by simply changing the data cards in the program listed in the appendix. This also enables the same program to be extended to other situations in other buildings.

Recommendations for Implementation of Results

All of the problems of the operations and maintenance function at Suburban Park School District could not be fully researched in a study of this length. Many other possibilities for related research were revealed to the members of the research team throughout this project. However, this study was confined to those aspects which coincided with the basic objectives as approved in our original proposal.

On the basis of findings of this study, the following recommendations are submitted to the Suburban Park School District:

Recommendation No. 1: Re-evaluate the work assignments and task efficiencies of custodians numbers 5 and 7. Figure 4 (page 17) indicates that these custodians are working at a performance level which is significantly sub-standard. Possible reasons for this inefficiency are individual differences of ability or incorrect estimates of their time allocation. The custodial supervisor should analyze the performance of the two men in question to confirm the accuracy of the findings, in comparison to the performance standards. If the re-evaluation confirms the above findings, an administrative decision may be in order.

Recommendation No. 2: Maintain present custodial staff size. Although Figure 1 indicates a disproportionate expenditure for custodial salaries, other findings of this study reveal that the custodial staff size is congruent with the needs of the Suburban Park facilities. The average demand placed upon the custodian is 104 per cent. However, this demand level is not considered significant to warrant an increase in custodial staff size under present operating practice. It appears that unless additional work assignments are made or there is a building expansion, the custodial staff size is near optimum.

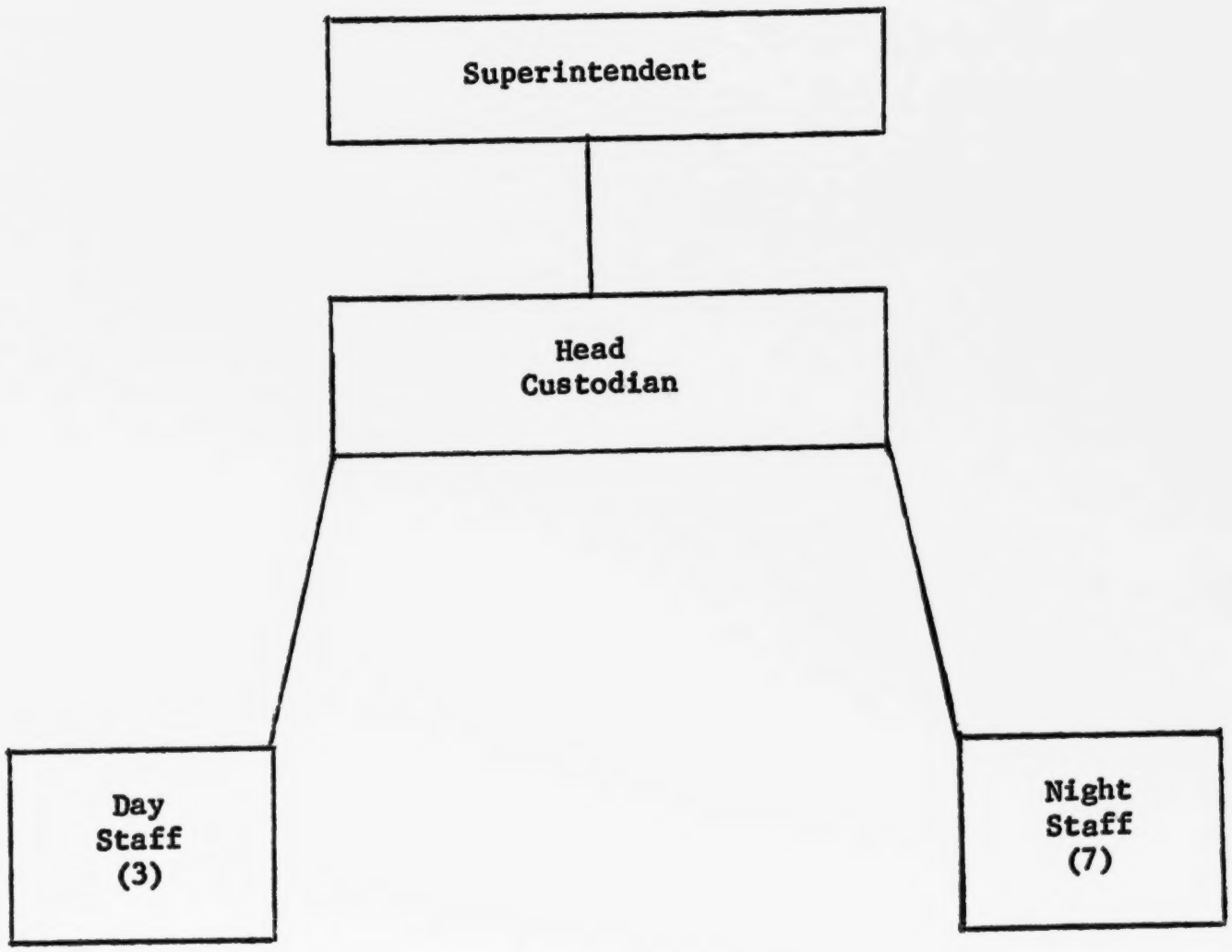
Recommendation No. 3: Re-assign individual custodial workloads to promote equalization of assigned duties. Figure 6 reveals a disparity of task equalization in regard to tasks assigned to custodian numbers 1, 2, 5, and 6. Based upon the findings of their report, the custodial supervisor should attempt to redistribute work tasks in situations wherever it is feasible.

Recommendation No. 4: Purchase the optimal mix of cleaning machines within the constraints of the decision variables. The computer printout of the custodial cost matrix (in Appendix E) presents the cleaning costs associated with the number of cleanings required per year and the various combinations of large and small machines. Minimization of cleaning costs is a function of administrative decisions regarding required annual cleanings, capital budget constraints upon the equipment investment, and desired flexibility in custodial task assignments. It is assumed in this report that the custodial time saved through machine usage will be allocated to improving the quality of the present tasks performed.

APPENDICES

APPENDIX A

ORGANIZATION OF CUSTODIAL STAFF



APPENDIX B

INVENTORY OF SUBURBAN PARK MAINTENANCE EQUIPMENT

GROUNDS:

A. 3/4 ton 4-wheel drive Int'l. pick-up truck

   1. 8-foot mower attachment

   2. 10-foot aerator

   3. 8-foot fertilizer

B. Int'l. Cub tractor with 5-foot rotary mower

C. 3 - 21" self-propelled mowers

BUILDING:

A. Floor polishers

   1. One 20", three 19", one 16"

B. Vacuum Cleaners

   1. Four tank type wet or dry models

   2. One Electrolux model

   3. Two hand vacuums

C. Assorted brooms, mops, and miscellaneous tools

APPENDIX C

DEFINITIONS OF TERMS USED

NCE - NET CURRENT EXPENDITURES - actual expenditures for the educational program. This includes the categories of administration, attendance and health, instructional salaries and supplies, secretarial and clerical help, fixed charges, plant maintenance and operation.

ADA - AVERAGE DAILY ATTENDANCE - in a given school year, the aggregate days attendance of the school divided by the number of days the school was actually in session.

EPU - EXPENDITURE PUPIL UNITS - or pupil units - the denominator used to compute the distribution of state aid. Pupil units for each resident pupil in average daily attendance is counted as follows:

Kindergarten pupils attending half-day sessions - ½ average daily attendance pupil unit.

Elementary pupils attending full day sessions - 1 average daily attendance pupil unit.

Secondary pupils, including junior high - 1½ average daily attendance pupil units.

Area vocational - technical pupils - 1½ average daily attendance pupil units.

PLANT MAINTENANCE - Those activities connected with keeping grounds, equipment, and buildings in their original condition.

SALARIES - full-time, part-time, and prorated salaries of district employees.

CONTRACTED SERVICES - labor and other expenditures for maintenance by personnel not on the payroll of the school district.

TOTAL MAINTENANCE - all above plus replacements of instructional equipment such as desks, tables, chairs, book cases, typewriters, etc., repair of buildings and rental of equipment.

APPENDIX C - (cont.)

PLANT OPERATION - Those activities concerned with keeping the physical plant open and ready for use. Includes lighting, heating, cleaning, communication, handling stores, caring for ground, etc.

SALARIES - same full-time, part-time, and prorated salaries of district employees.

CONTRACTED SERVICES - labor and other expenditures for operation by personnel not on the payroll of the school district.

TOTAL - above plus fuel, utilities, electricity, gas, telephone, custodial supplies, etc.

APPENDIX D

CUSTODIAL CLEANING ASSIGNMENT
(Job Description)

Custodian _____ Building _____

Hours: from _____ to _____ Total No. Custodians _____

Floor or area _____ Head Custodian _____

CLASSROOMS

Total No. of Classrooms cleaned _____ Av. Size of Classroom _____
Total Sq. Ft. of Classroom space cleaned _____
Approximate time USED TO CLEAN classrooms _____
Room Numbers Describe daily cleaning operations

CORRIDORS

Total Sq. Ft. of corridor area cleaned _____
Approximate time used to clean corridors _____
Corridor floor material _____ Condition _____ Lockers? _____
Describe daily cleaning operations:

LAVATORIES

Number of Lavatory Rooms cleaned _____
Total number of fixtures involved _____
Floor Material _____ Condition _____
Wall Material _____ Condition _____
Approximate time used to clean Lavatories _____
Describe daily cleaning operations:

STAIRWAYS

Total number of stairways (one floor to next floor) _____
Approximate time used to clean stairways _____

OTHER AREAS OR SPECIAL DUTIES

Describe Area (A) _____ Total Sq. Ft. _____
Describe Area (B) _____ Total Sq. Ft. _____
Describe Area (C) _____ Total Sq. Ft. _____
Approximate time used to clean other areas _____
Describe daily cleaning operations:

Describe Special Duties:

Approximate time used for special duties _____

APPENDIX E

THIS IS THE COST MATRIX

MACH COMB	0,0	0,2	0,4	0,6	0,8	1,2	1,4	1,6	1,8	2,2	2,4	2,6	2,8
1	840.00	581,50	919.00	1256,50	1594,00	1000,75	1338,25	1675,75	2013,25	1473,25	1810,75	2148,25	2485,75
2	1680.00	825,50	1163.00	1500,50	1838,00	1191,50	1529,00	1866,50	2204,00	1664,00	2001,50	2339,00	2676,50
3	2520,00	1069,50	1407,00	1744,50	2082,00	1382,26	1719,76	2057,26	2394,76	1854,76	2192,26	2529,76	2867,26
4	3360,00	1313,50	1651,00	1988,50	2326,00	1573,01	1910,51	2248,01	2585,51	2045,51	2383,01	2720,51	3058,01
5	4200,00	1557,50	1895,00	2232,50	2570,00	1763,76	2101,26	2438,76	2776,26	2236,26	2573,76	2911 26	3248,76
6	5040,00	1801,50	2139,00	2476,50	2814,00	1954,51	2292,01	2629,51	2967,01	2427,01	2764,51	3102 01	3439,51
7	5880,00	2045,50	2383,00	2720,50	3058,00	2145,26	2482,76	2820,26	3157,76	2617,76	2955,26	3292,76	3630,26
8	6720,00	2289,50	2627,00	2964,50	3302,00	2336,01	2673,51	3011,01	3348,51	2808,51	3146,01	3483,51	3821,01
9	7560,00	2533,50	2871,00	3208,50	3546,00	2526,77	2864,27	3201,77	3539,27	2999,27	3336,77	3674,27	4011,77
10	8400,00	2777,50	3115,00	3452,50	3790,00	2717,52	3055,02	3392,52	3730,02	3190,02	3527,52	3865,02	4202,52
11	9240,00	3021,50	3359,00	3696,50	4034,00	2908,27	3245,77	3583,27	3920,77	3380,77	3718,27	4055,77	4393,27
12	10080,00	3265,50	3603,00	3940,50	4278,00	3099,02	3436,52	3774,02	4111,52	3571,52	3909,02	4246,52	4584,02

INITIAL INVESTMENT COST

0 1500.00 3000,00 4500,00 6000,00 3600,00 5100,00 6600,00 8100,00 5700,00 7200,00 8700,0010200.00

NUMBERS OF HOURS NEEDED FOR OPERATION

300.00 40.00 20.00 13.33 10.00 26,67 13.33 8,89 8.51 26,67 13.33 8,89 6.67

DATA INPUT

SQFL	SQFS	COSTL	COSTS	SQFML	SQFMS	AGEL	AGES	SQFMM	COSTMM	AINT	OPCML	OPCMS
40000.0080000,00		2100,00	750,00	4700,00	1500,00	5,00	5,00	400,00	2,80	.05	.50	.25

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